LMS/SHL/S11217

2013 Groundwater Monitoring Report Project Shoal Area Subsurface Corrective Action Unit 447

February 2014

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Abbreviations

AEC	U.S. Atomic Energy Commission
amsl	above mean sea level
bgs	below ground surface
BSZ	bottom of open interval/screen zone
^{14}C	carbon-14
CADD	Corrective Action Decision Document
CAP	Corrective Action Plan
CAU	Corrective Action Unit
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FFACO	Federal Facility Agreement and Consent Order
ft	feet
^{129}I	iodine-129
LM	Office of Legacy Management
MCL	maximum contaminant level
MDC	minimum detectable concentration
µg/L	micrograms per liter
µmhos/cm	micromhos per centimeter
MV	monitoring/validation
NDEP	Nevada Division of Environmental Protection
pCi/L	picocuries per liter
PSA	Project Shoal Area
RDL	required detection limit
SCM	site conceptual model
TOC	top of casing
TVD	true vertical depth
^{234}U	uranium-234
^{238}U	uranium-238

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Executive Summary

The Project Shoal Area (PSA) in Nevada was the site of a 12-kiloton underground nuclear test in 1963. Although the surface of the site has been remediated, investigation of groundwater contamination resulting from the test is still in the corrective action process. Annual sampling and hydraulic head monitoring are conducted at the site as part of the subsurface corrective action strategy. Analytical results from the 2013 monitoring are consistent with those of the previous years in that the only tritium detected was in samples collected from well HC-4. The concentration of tritium in this well was below the U.S. Environmental Protection Agency (EPA)-established maximum contaminant level (MCL) of 20,000 picocuries per liter (pCi/L) and below the high of 1,130 pCi/L reported in 1998 (Pohll et al. 1998). Total uranium and gross alpha were detected in samples collected from wells HC-2, HC-4, and HC-6 at concentrations above the EPA-established MCLs of 30 micrograms per liter and 15 pCi/L, respectively. If the gross alpha values in these samples are adjusted by subtracting activities of the uranium isotopes, the values are less than zero, indicating that uranium accounts for all or nearly all gross alpha activity in these samples. The total uranium concentrations obtained from this monitoring period were consistent with previous results and reflect a slightly elevated natural uranium concentration, consistent with the mineralized geologic terrain. Isotopic ratios of uranium also indicate a natural source of uranium in groundwater rather than a nuclear-test-related source. Water level trends obtained from the 2013 water level data were consistent with those of previous years.

The corrective action strategy for the PSA is currently focused on revising the site conceptual model (SCM) and evaluating the adequacy of the current monitoring well network. Some aspects of the SCM are known; however, two major concerns are the uncertainty in the groundwater flow direction and the cause of rising water levels in site wells west of the shear zone. Water levels have been rising in the site wells west of the shear zone since the first hydrologic characterization wells were installed in 1996. While water levels in wells west of the shear zone continue to rise, the rate of increase is less than in previous years. The SCM will be revised, and an evaluation of the groundwater monitoring network will be conducted when water levels at the site have stabilized to the mutual agreement of U.S. Department of Energy Office of Legacy Management and Nevada Division of Environmental Protection.

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1.0 Introduction

This report presents the 2013 groundwater monitoring results collected by the U.S. Department of Energy (DOE) Office of Legacy Management (LM) at the Project Shoal Area (PSA) Subsurface Corrective Action Unit (CAU) 447 in Churchill County, Nevada. Responsibility for the environmental site restoration of the PSA was transferred from the DOE Office of Environmental Management to LM on October 1, 2006. The environmental restoration process and corrective action strategy for CAU 447 are conducted in accordance with the *Federal Facility Agreement and Consent Order (FFACO)* (NDEP 1996, as amended) and all applicable Nevada Division of Environmental Protection (NDEP) policies and regulations. The corrective action strategy for the site includes monitoring in support of future site closure. This report summarizes the results from the groundwater monitoring program during fiscal year 2013.

2.0 Site Location and Background

The PSA is south of U.S. Highway 50, approximately 30 miles southeast of Fallon, in Churchill County, Nevada (Figure 1). The Project Shoal underground nuclear test was performed on October 26, 1963, as part of the Vela-Uniform program sponsored jointly by the U.S. Department of Defense and the U.S. Atomic Energy Commission (AEC). The test consisted of detonating a 12-kiloton nuclear device in granitic rock at a depth of approximately 1,211 feet (ft) below ground surface (bgs) (AEC 1964). A cavity created by the test collapsed shortly after the detonation and formed a rubble chimney (Pohll et al. 1998). The radius of the cavity is reported to be 85 ft (26 meters) (Hazleton-Nuclear Science Corporation 1965).

Site deactivation and post-shot drilling activities began on October 28, 1963. Re-entry drilling indicated that the Shoal rubble chimney extended approximately 356 ft above the shot point (Hazleton-Nuclear Science Corporation 1965). The decontamination and restoration activities were minimal, because no large areas of surface radiological contamination were found during or following the test. During the cleanup effort, the emplacement shaft was covered with a concrete slab, and the particle motion, exploratory core holes, and U.S. Bureau of Mines boreholes on the site were plugged and abandoned. A radioactive materials survey conducted at the surface of the site in 1970 indicated that no radiological levels exceeded background for the area (AEC 1970).

2.1 Summary of Corrective Action Activities

Surface and subsurface contamination resulted from the underground nuclear test at PSA. To address these areas of contamination, surface and subsurface CAUs were identified, and the areas of contamination were addressed through separate corrective action processes. The surface CAU included three Corrective Action Sites that consisted of a mud pit with drilling mud impacted by petroleum hydrocarbons; a muckpile of granite that remained from excavation of the emplacement shaft; and housekeeping areas that consisted of approximately 20 rusted and empty oil cans. Remediation of surface CAU 416 was completed in 1998 and is summarized in the *Closure Report for CAU No. 416, Project Shoal Area* (DOE/NV 1998). NDEP approved the Closure Report on February 13, 1998, stating that no post-closure monitoring is required, and no land use restrictions apply at CAU 416 (NDEP 1998).

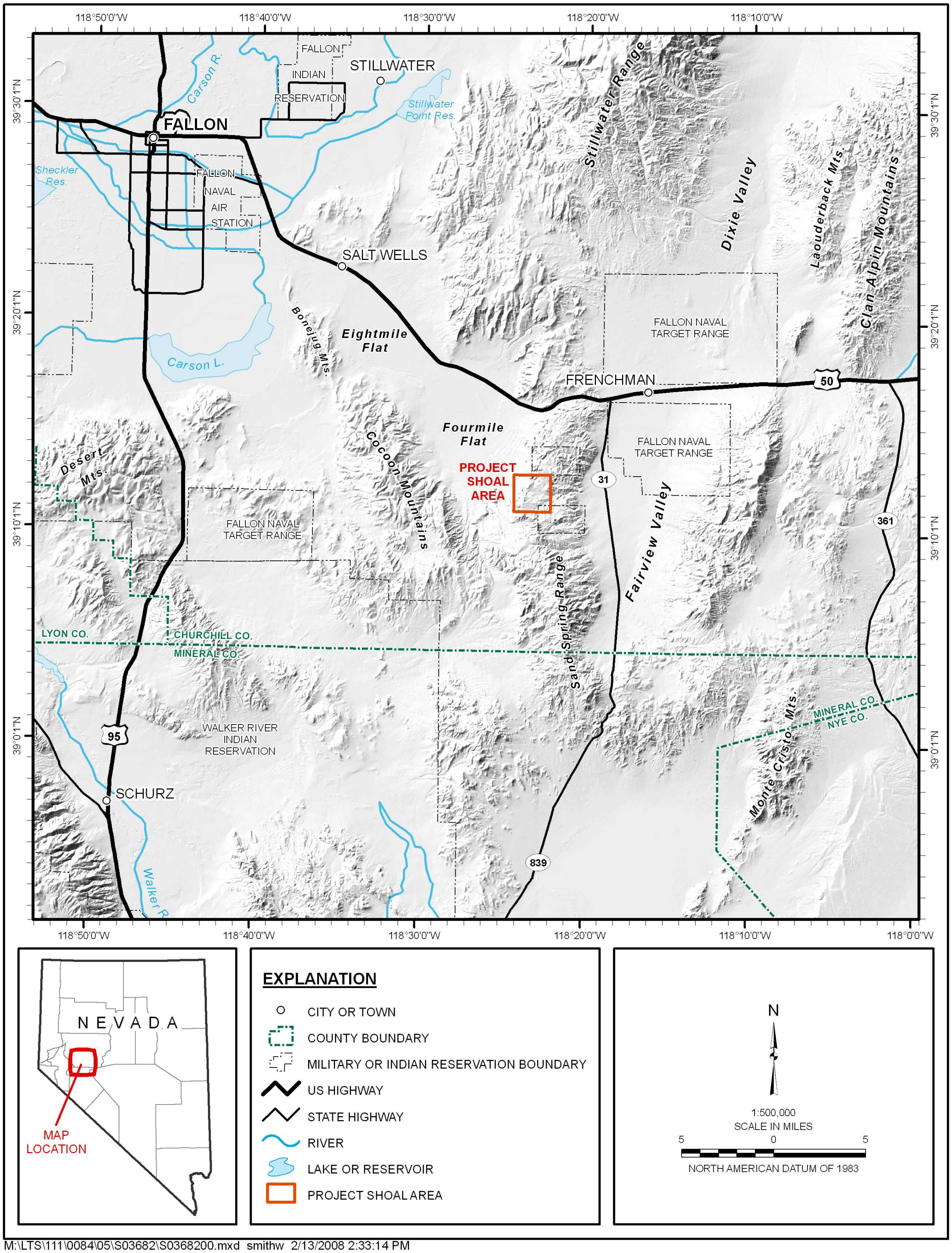

Figure 1. Location of the Project Shoal Area

The corrective action process for the subsurface has not been completed, and there is currently no known technology to remediate the remaining subsurface radioactive contamination at the site. The original corrective action strategy for the subsurface used a groundwater flow and transport model developed by Desert Research Institute to help evaluate data and select a corrective action alternative. The model results were used to determine a contaminant boundary and establish a restricted region surrounding the site. The contaminant boundary (Figure 2) is a probabilistic forecast of the maximum extent over 1,000 years of radionuclide transport where test-related radionuclides in groundwater outside the boundary have a 5 percent or less likelihood of exceeding the radiological standards of the Safe Drinking Water Act. NDEP approved the contaminant boundary as the compliance boundary in their letter dated January 19, 2005 (NDEP 2005). The corrective action alternative selected for the site includes monitoring with institutional controls and is presented in the Corrective Action Decision Document/Corrective Action Plan (CADD/CAP; DOE/NNSA 2006).

As part of the original corrective action strategy, three monitoring/validation (MV) wells (MV-1, MV-2, and MV-3) were installed in 2006 for the dual purpose of monitoring for contaminant migration and evaluating the flow and transport model results. The site conceptual model (SCM) is being reevaluated to address inconsistencies with the numerical model predictions and monitoring well data. Concerns with the model stem from two observations. First, the horizontal component of groundwater flow predicted by the model was primarily toward the north-northeast, whereas horizontal gradients inferred from water levels measured in site wells do not support the modeled flow direction. Second, the model incorrectly assumed that the groundwater flow system is in a steady state; in fact, water levels west of the shear zone have been rising approximately 1 to 2 ft per year during the time they have been monitored, beginning with the installation of the HC wells in the late 1990s. Water levels were not monitored at the site, except for the adjacent valleys, prior to the installation of the HC wells and later MV wells. Pursuant to the FFACO (NDEP 1996, as amended), LM began implementing a new corrective action strategy for the site in 2009.

On November 24, 2009, LM submitted an initial Short-Term Data Acquisition Plan to NDEP, detailing data collection activities that included a surface geophysical program and enhanced groundwater monitoring. The completed geophysical program included seismic and electromagnetic surveys. As part of the evaluation of data obtained from the surveys, a technical exchange meeting was conducted in March 2011 with the geophysicists who performed the surveys (Lee Liberty from Boise State University and Jim Hasbrouck from Hasbrouck Geophysics), Desert Research Institute, and NDEP to discuss the results and potential site conceptual models. During the meeting it was agreed that further understanding of the groundwater flow system was needed for the enhancement of potential SCMs and that a new Short-Term Data Acquisition Plan was necessary to outline future activities at the site. The Surface Geophysics Report recommended that geophysical data be evaluated further and compared to existing data to assess and enhance any potential SCMs (DOE 2011b). The technical exchange and Surface Geophysics Report provided the basis for developing the new Data Acquisition Plan that was submitted to NDEP in October 2011.

The 2011 data acquisition plan included further review of available reports and preparation of a detailed information resource tool that includes a summary of pertinent technical data. Analytical, hydrologic, and geologic data obtained from the evaluation of historical reports have been reviewed with existing data and collected geophysical data to help identify geologic structures that might be influencing groundwater flow at the site. These data have been assembled for three-dimensional visualization. Revisions to the SCM and enhancements to the monitoring well network will be provided to NDEP in an addendum to the CADD/CAP (DOE/NNSA 2006).

3.0 Geologic and Hydrologic Setting

The PSA is in the northern portion of the Sand Springs Range in west-central Nevada’s Churchill County. The Sand Springs Range is the southern extension of the Stillwater Range, a north-northeast-trending fault block range that traverses Churchill County. The Sand Springs Range rises to an elevation of approximately 6,751 ft above mean sea level (amsl) and is flanked by Fourmile Flat to the west and Fairview Valley to the east (Figure 1). The Shoal site is in Gote Flat at an elevation of approximately 5,250 ft amsl and is within an area that is part of the Cretaceous-age Sand Springs granitic batholith.

The Sand Springs batholith is composed of granodiorite and granite, aplite, and pegmatite dikes; andesite dikes; rhyolite dikes; and rhyolitic intrusive breccia. Internal deformation of the Sand Springs granite is largely by high-angle normal faults and fractures distributed between two dominant structural trends that strike approximately N 50^{o} W and N 30^{o} E and are vertical to steeply dipping. Several dikes of varying composition predominantly follow the same two orientations and intrude along these lines of preexisting weakness. These orthogonal-type sets of faults and fractures appeared early in the history of the Sand Springs granite and affected much of the subsequent structural and chemical evolution of this large intrusion (Beal et al. 1964).

The water table beneath the site (near surface ground zero and west of the shear zone) occurs at depths ranging from approximately 965 to 1,090 ft bgs, and groundwater moves primarily through fractures in the granite. Recharge occurs by infiltration of precipitation on the mountain range, and regional discharge occurs in the adjacent valleys. A shear zone, located about 1,500 ft east of surface ground zero (Figure 2 and Figure 3), is interpreted as a barrier to groundwater flow on the basis of disparate head levels in wells separated by the shear zone (Carroll et al. 2001). Groundwater within Fairview Valley to the east has been used for ranching, seasonal residential purposes, and military purposes within the last 5 years.

4.0 Monitoring Program and Objectives

The primary objectives of the monitoring program are (1) “detection monitoring” to identify any migration of radiologic contamination from the test cavity and (2) “system monitoring” to obtain hydraulic head data for monitoring the overall stability (quasi-steady state) of the hydrogeologic system. The monitoring program and objectives were established in the CADD/CAP, and the program was initiated after NDEP approved the CADD/CAP and wells MV-1, MV-2, and MV-3 were installed in 2006. Enhancements were made to the monitoring program after the numerical model could not be verified against data obtained from the MV wells (MV-1, MV-2, and MV-3). The enhancements are documented in short-term data acquisition plans that were completed in 2009 and 2011 to support the CADD/CAP and provide interim guidance documents until an addendum to the CADD/CAP can be completed. The *Sampling and Analysis Plan for U.S. Department of Energy Office of Legacy Management Sites* (LMS/PLN/S04351) is used to guide the quality assurance/quality control of the annual sampling and monitoring program.

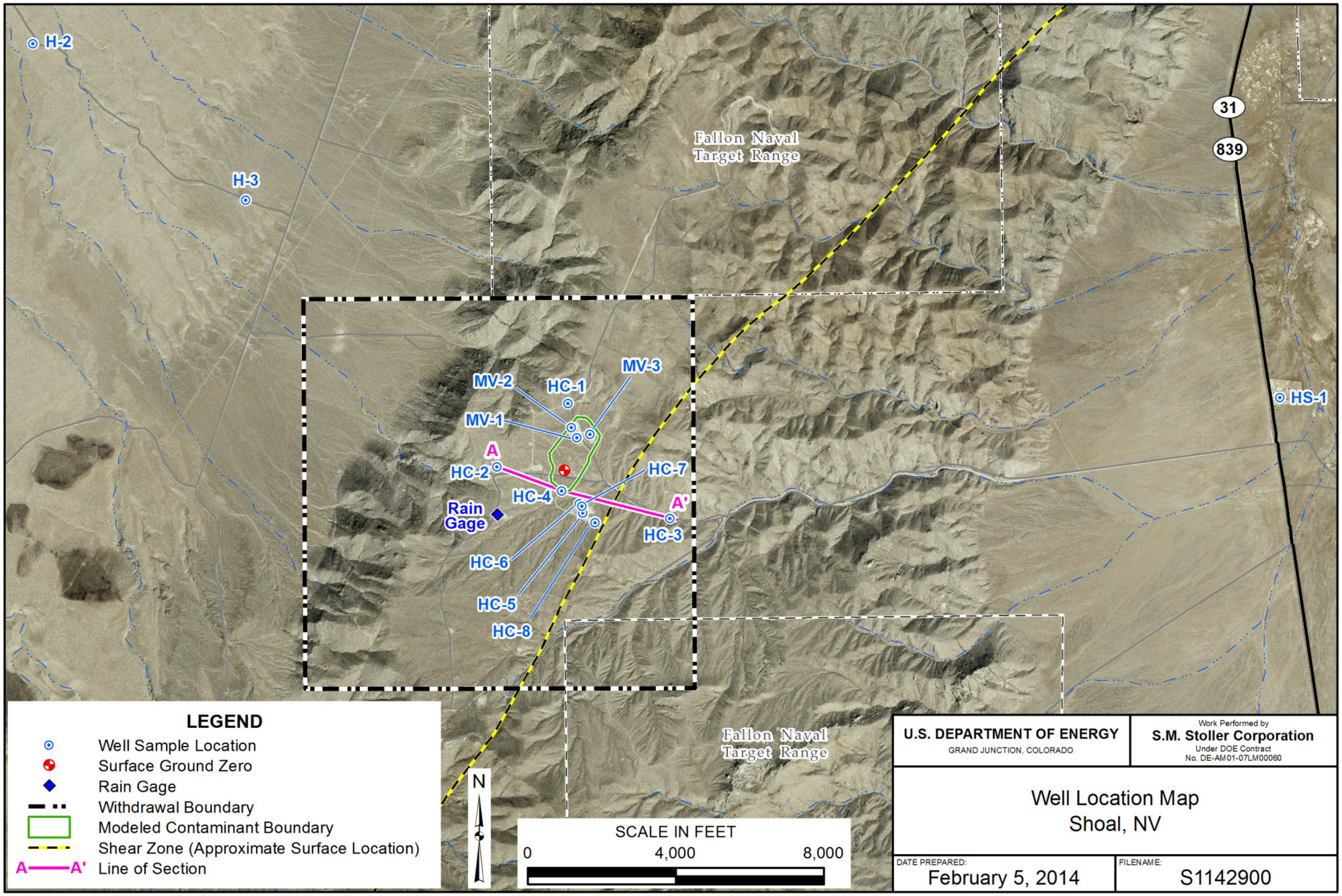

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Figure 2. Well Locations, Shoal, Nevada

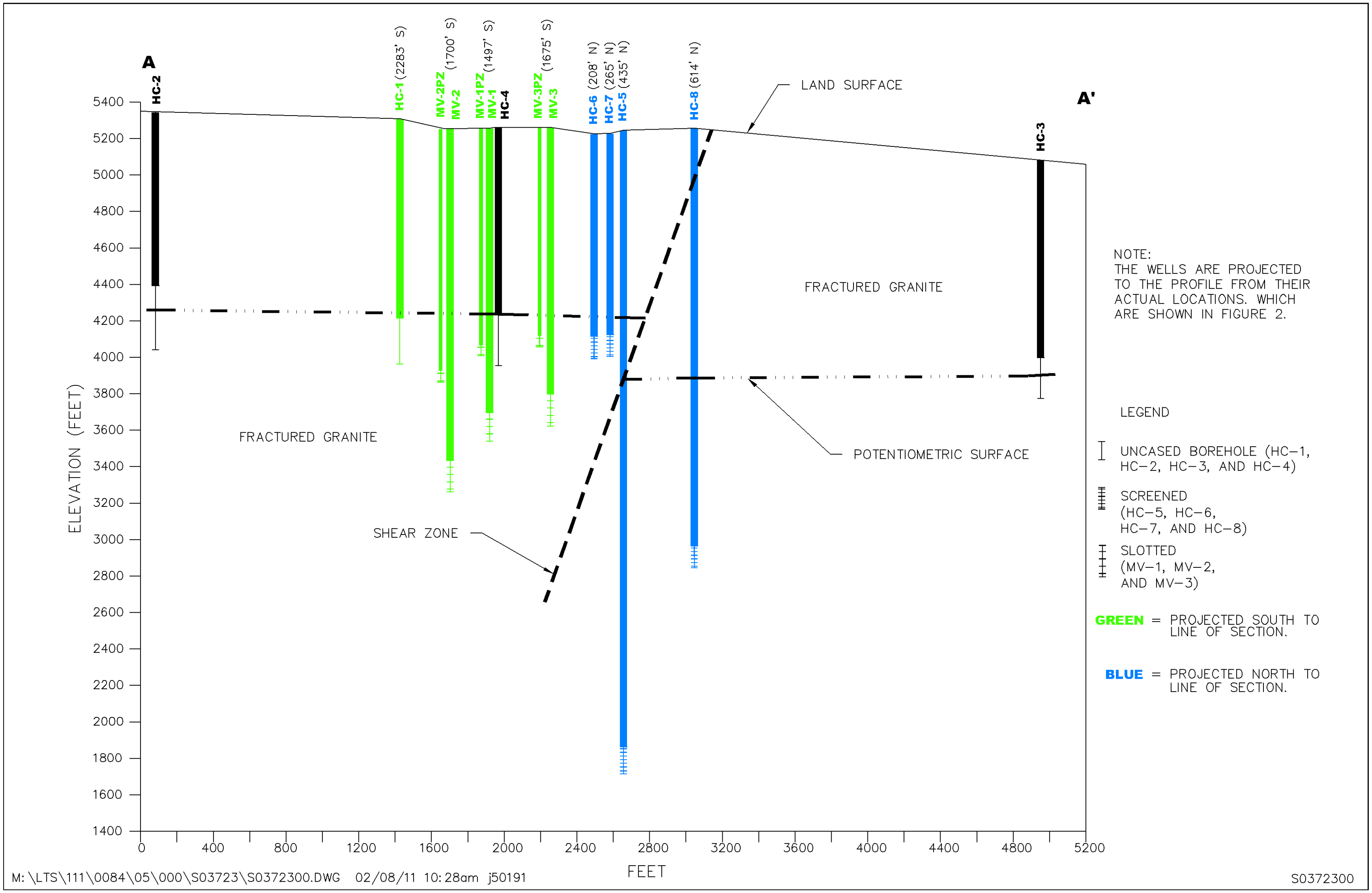

Figure 3. Cross Section A–A' Depicting Monitoring Well and Shear Zone Location, Project Shoal Area, Nevada

The corrective action strategy is focused on revising the SCM and evaluating the adequacy of the current monitoring well network. Aspects of the SCM are currently known; however, two major concerns are the uncertainty in the groundwater flow direction and the cause of the rising water levels in site wells that are west of the shear zone. Water levels have been rising in the site wells west of the shear zone since the first wells were installed in 1996. LM continues to evaluate site data to enhance the SCM and monitor water levels as part of the ongoing groundwater monitoring program, which includes collecting samples for laboratory analysis, measuring depth to groundwater and downloading transducers in site monitoring wells, and downloading the rain gage that was installed at the site in August 2012 (Figure 2). The 2013 monitoring program was enhanced to include supplemental activities that were specified in the 2013 Sampling Plan (DOE 2013a). Results from the monitoring program are provided below, and results from the supplemental activities are provided in Section 5.0.

4.1 Radioisotopic Monitoring

Groundwater samples were collected from wells MV-1, MV-2, MV-3, HC-1, HC-2, HC-3, HC-4, HC-5, HC-6, HC-7, and HC-8 during the May 2013 sampling event. Monitoring wells MV-1, MV-2, MV-3, HC-4, HC-5, HC-7, and HC-8 were purged prior to sampling using dedicated submersible pumps. At least one well casing volume was removed, and field parameters (temperature, pH, and specific conductance) were allowed to stabilize before samples were collected (Appendix A; Table A-1). Samples were collected from wells HC-1, HC-2, HC-3, and HC-6 using a depth-specific bailer because these wells are not completed with dedicated submersible pumps. The analytical results obtained from the annual sampling were validated in accordance with the *Environmental Procedures Catalog* (LMS/PRO/S04325), "Standard Practice for Validation of Laboratory Data." A copy of the Data Validation Package is maintained in the LM records and is available on request. The final measurements of field parameters and well purge volumes are presented in Appendix A (Table A-1).

Groundwater samples collected as part of the annual monitoring event were analyzed for tritium, uranium isotopes, gross alpha, and mass concentrations of uranium as specified in the Short-Term Data Acquisition Plans (DOE 2009 and 2011a), which enhanced the monitoring network defined in the CADD/CAP (DOE/NNSA 2006). The Short-Term Data Acquisition Plans also reduced the frequency for analyzing samples for carbon-14 (^{14}C) and iodine-129 (^{129}I) to every 5 years beginning after the 2010 sampling event (DOE 2009 and 2011a). Tritium is the analyte selected as an indicator of contaminant migration from the cavity due to its mobility and abundance in the first 100 years of the post-shot monitoring period. However, because of tritium's short half-life, monitoring of ^{14}C and ^{129}I is also conducted in support of long-term post-closure monitoring. Gross alpha is included in the analytical suite because elevated concentrations of gross alpha have been detected in the past at the PSA. The U.S. Environmental Protection Agency (EPA)-established maximum contaminant level (MCL) for gross alpha is exclusive of uranium and radon. Including uranium and uranium-isotopic analyses as part of the analytical suite provides data to demonstrate that the elevated concentrations of gross alpha are from natural sources. Radon is not included in the analytical suite because it volatilizes during analysis and is an insignificant contributor to gross alpha.

The CADD/CAP established regulatory levels for site groundwater of 20,000 picocuries per liter (pCi/L) tritium, 2,000 pCi/L ^{14}C, and 1 pCi/L ^{129}I (DOE/NNSA 2006). These levels are not to be exceeded outside the compliance boundary, which is the modeled contaminant boundary (Figure 2). The EPA-established MCLs for gross alpha and uranium are 15 pCi/L and

30 micrograms per liter (µg/L), respectively. These constituents are believed to be naturally elevated in groundwater in the region. The LM required detection limit (RDL) for tritium is 400 pCi/L, which is slightly higher than the limit of 300 pCi/L established in the CADD/CAP. A record of technical change was submitted to NDEP and approved in March 2012 to change the RDL to 400 pCi/L in the CADD/CAP. The laboratory radiochemical minimum detectable concentration (MDC) reported with these data is an a priori estimate of the detection capability of a given analytical procedure, not an absolute concentration that can or cannot be detected.

4.2 Radioisotopic Results

Table 1 presents a summary of analytical results for ^{14}C, ^{129}I, tritium, uranium, and gross alpha obtained from the samples collected in 2011 through 2013. Analytical results obtained from when the CADD/CAP monitoring program began in 2007 through the present are provided in Appendix B (Tables B-1 and B-2). A time-concentration plot for well HC-4 (Figure 4) presents tritium results obtained from the CADD/CAP monitoring program and sampling events performed by the EPA and Desert Research Institute before the CADD/CAP monitoring program was initiated in 2007. Well HC-4 was installed in 1996 and is the only well that has had detections of tritium above the laboratory's MDC using conventional laboratory methods. The presence of tritium in this well is attributed to its proximity to the nuclear detonation (Figure 2). This interpretation of the tritium source is supported by the elevated levels of ^{14}C detected in samples collected from well HC-4 compared to levels in samples from the other monitoring wells (Table 1 and Appendix B, Table B-1). The elevated concentration of ^{14}C in this well is likely the result of its migration in the gas phase near the water table, as part of the carbon dioxide (CO_2) molecule, where it dissolved into groundwater in the upper saturated zone near the detonation.

Samples collected from well HC-4 during the May 2013 sampling event were the only samples with tritium detected above the laboratory's MDC. Tritium levels in well HC-4 (Figure 4) were typically above laboratory MDCs from the mid-1990s until 2006, though some duplicate analyses were below MDCs. Tritium levels have been trending lower and were below the laboratory MDC for the 2005 and 2007 sampling events (Figure 4). Of the two samples analyzed in 2008 (one by the EPA and one by Paragon), results were above the MDC for one sample and below the MDC for the other. Since 2008, tritium results have increased from a concentration that was below the laboratory MDC in 2007 to concentrations above the MDC, ranging from 434 pCi/L in 2009 to 964 pCi/L in 2013. The variation in tritium concentrations in this well is likely related to the different volumes of groundwater removed during the sampling events. The highest tritium concentration of 1,130 pCi/L was from a sample collected in 1997 by Desert Research Institute after approximately 1,100 gallons of groundwater were removed during an aquifer test. The volume of groundwater removed from well HC-4 was increased during the 2012 and 2013 sampling events to 700 gallons (1 well volume), which resulted in a tritium concentration of 803 pCi/L and 964 pCi/L, respectively. From 2007 through 2011 the well purge volumes for this well ranged from 200 to 420 gallons. These volumes were less than one well volume because of a misunderstanding in the well configuration. The samplers assumed that the 5.5-inch casing diameter at the surface extended to the total depth of the borehole. However, the 5.5-inch casing only extends to 1,013 ft bgs, with open 8-inch borehole from 1,013 to 1,303 ft bgs. The assumed smaller radius for the entire well resulted in a purge volume calculation less than one well volume. The well purge volumes are not available for samples collected by EPA prior to 2007, with the exception of the sample collected by Desert Research Institute in 1997.

Table 1. Radioisotopic and Chemical Sampling Results 2011 through 2013

Monitoring Location	Date	Carbon-14 (pCi/L)	Iodine-129 (pCi/L)	Tritium (pCi/L)	Uranium (µg/L)	Gross Alpha (pCi/L)
MV-1	3/22/2011	NA	NA	<350	25	16.6
	3/22/2011[a]	NA	NA	<360	25	14.3
	5/25/2012	NA	NA	<300	22	14.3
	5/22/2013	NA	NA	<370	21	13.6
MV-2	3/22/2011	NA	NA	<350	23	9.92
	5/24/2012	NA	NA	<300	22	10.6
	5/22/2013	NA	NA	<320	22	9.79
MV-3	3/22/2011	NA	NA	<350	5.8	4.98
	5/25/2012	<RDL (0.0106)	NA	<300	7	2.72
	5/21/2013	NA	NA	<340	8	5.08
	5/21/2013[a]	NA	NA	<380	8	5.84
HC-1	3/22/2011	NA	NA	<360	1.6	2.19
	5/23/2012	<RDL (0.0123)	NA	<300	1.1	<0.75
	5/22/2013	NA	NA	<340	0.9	3.19
HC-2	3/22/2011	NA	NA	<360	120	197
	5/22/2012	NA	NA	<300	110	64.5
	5/22/2013	NA	NA	<330	100	61.1
HC-3	3/22/2011	NA	NA	NA	NA	NA
	5/23/2012	<RDL (0.0145)	NA	<300	2	0.283
	5/22/2013	NA	NA	<350	2.7	0.724
HC-4	3/23/2011	NA	NA	554	8.9	3.82
	5/24/2012[a]	NA	NA	774	46	16.7
	5/24/2012	<RDL (2.50)	NA	803	46	22.9
	5/21/2013	NA	NA	964	60	35.1
HC-5	3/23/2011	NA	NA	<360	0.45	<2.1
	5/23/2012	<RDL (0.00370)	NA	<300	0.49	0.349
	5/22/2013	NA	NA	<340	0.40	0.957
HC-6	3/23/2011	NA	NA	<360	37	20.4
	5/23/2012	<RDL (0.0116)	NA	<300	38	14.1
	5/22/2013	NA	NA	<360	36	19.1
HC-7	3/23/2011	NA	NA	<360	13	10.6
	5/23/2012	NA	NA	<300	41	23.9
	5/21/2013	NA	NA	<370	15	13.8
HC-8	3/23/2011	NA	NA	NA	NA	NA
	5/25/2012	NA	NA	<300	0.20	0.454
	5/23/2013	NA	NA	<380	0.14	1.24

[a] Indicates a duplicate sample.
<RDL = below required detection limit with laboratory result in parentheses; RDL is 5 pCi/L for ^{14}C, 0.1 pCi/L for ^{129}I, 400 pCi/L for tritium, 50 µg/L for uranium, and 4 pCi/L for gross alpha (DOE/NNSA 2006).
NR = not run, because sample bottle was broken during shipment to the laboratory.
NA = not applicable (samples not collected or samples not analyzed).

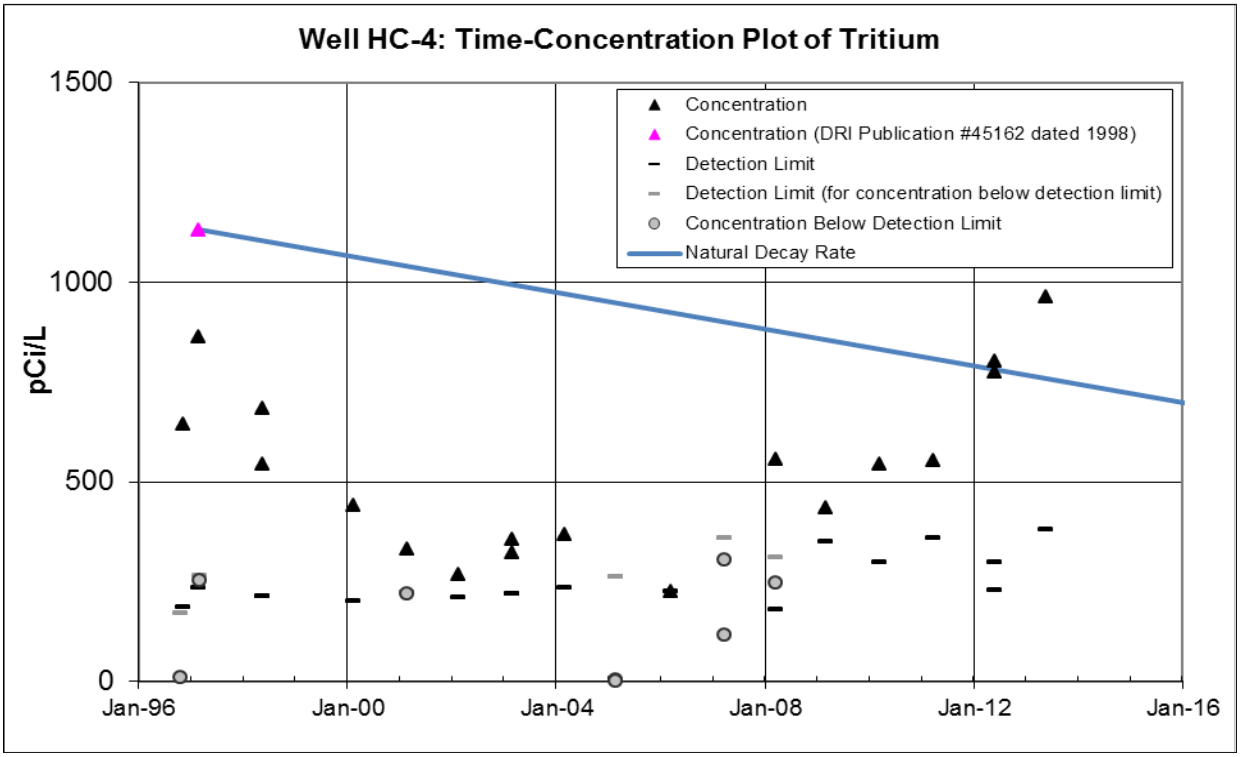

Figure 4. Time-Concentration Plot of Tritium at Well HC-4

Samples collected from wells MV-1 and MV-2 in 2007 (Appendix B, Table B-1) had detectable gross alpha activity and uranium mass concentrations above the EPA-established MCLs of 15 pCi/L and 30 µg/L, respectively. Concentrations in samples collected from these wells in 2008 declined below the EPA-established MCLs and have remained relatively constant since then with the exception of the sample collected from well MV-1 in 2011, in which the gross alpha concentration (16.6 pCi/L) exceeded the EPA-established MCL of 15 pCi/L. Analytical results obtained from the 2013 sampling event (Table 1) indicate that gross alpha activity and uranium mass concentrations were detected above the EPA-established MCLs in the samples from wells HC-2, HC-4, and HC-6. Historically, samples from wells HC-2 and HC-6 have had concentrations of gross alpha and uranium above the EPA-established MCLs, and this trend continued in 2013. Analytical results for samples from well HC-4 indicate a recent increase in gross alpha and uranium concentrations above the EPA-established MCLs starting in 2012. These increases may be attributed to an increase in the volume of groundwater removed from the well during sampling. The remaining analytical results for gross alpha and uranium obtained from the 2013 sampling event are consistent with previous results.

Bevans et al. (1998) demonstrated that concentrations of uranium are elevated in ambient groundwater in the region surrounding the site. The elevated uranium concentrations are attributed to leaching from granitic bedrock and associated sediments. If the gross alpha values for samples from wells HC-2, HC-4, and HC-6 (Table 1) are adjusted by subtracting activities of uranium-234 (^{234}U) and uranium-238 (^{238}U) shown in Table 2, values are less than zero, indicating that uranium accounts for all or nearly all gross alpha activity in these samples (see example calculation below for adjusted results). Isotopic ratios of uranium further support the interpretation of a natural source of uranium in groundwater rather than a nuclear-test-related source. Natural uranium-bearing systems typically have $^{234}U/^{238}U$ activity ratios near 1 (Cowart and Osmond 1977), which is indicative of secular equilibrium between the two isotopes. Table 2 indicates that most ratios observed in the samples range from 0.91 to 2.77—consistent with a natural uranium source. In contrast, average estimates of radionuclides resulting from nuclear tests at the Nevada National Security Site suggest a residual source term with a $^{234}U/^{238}U$ activity ratio of 56.25 (Smith 2001).

Example Calculation: Gross Alpha (pCi/L) – ^{234}U (pCi/L) – ^{238}U (pCi/L) = Adjusted Result

HC-2:	61.1 – 37.2 – 37.2 = −13.3
HC-4:	35.1 – 22.0 – 20.8 = −7.7
HC-6:	19.1 – 15.7 – 12.6 = −9.2

Note: Adjusted gross alpha results can be <0 due to laboratory measurement uncertainty.

4.3 Hydraulic Head Monitoring

The groundwater flow system was monitored by measurements of hydraulic head in the onsite wells/piezometers (MV-1 through MV-3 and HC-1 through HC-8) and offsite wells (H-2 and H-3) (Figure 2). Heads were recorded every 3 hours by transducers installed in these wells/piezometers. Water levels were measured manually, and transducers were downloaded in May as part of the annual sampling and in September as part of a scheduled monitoring event and site inspection. The manual water level measurements were collected prior to the occurrence of activities that would disturb ambient water level conditions. The manual water level measurements were used to convert the transducer data to groundwater elevations.

4.4 Hydraulic Head Results

Table 3 presents well construction information and the most recent hydraulic head data, obtained in September 2013. Hydrographs of hydraulic head data obtained from site wells and piezometers from when the CADD/CAP monitoring program was initiated in 2007 are shown in Figure 5, Figure 6, and Figure 7. Head data collected using a water level tape appear as individual symbols, and data collected with transducers appear as lines due to the recording frequency of every few hours. The hydrographs are grouped according to the location of the open interval of each well relative to the north-northeast-trending shear zone that transects the site. Monitoring locations west of the shear zone include the MV-1, MV-2, and MV-3 wells and piezometers and wells HC-1, HC-2, HC-4, HC-6, and HC-7 (Figure 5). Head levels east of the shear zone are monitored by wells HC-3, HC-5, and HC-8 (Figure 6). Monitoring locations in Fourmile Flat (west of the site) include the H-2 and H-3 wells (Figure 7). The hydrograph for the MV-2 piezometer was added to Figure 5 in 2012. The water level in this piezometer was recovering very slowly after its installation, and water was added in several stages until it began to take water, resulting in the current slowly declining water level that is not indicative of the head level in the formation at its screened interval. Once the water level stops declining and stabilizes, or begins to rise, the water level may then be representative of the formation at its screened interval. However, it may always be suspect due to the lack of fractures and low permeability of the MV-2 piezometer open interval.

Table 2. Uranium Isotopic Sampling Results, 2011 Through 2013

Monitoring Location	Date	Uranium-234 (pCi/L)	Uranium-238 (pCi/L)	Uranium-234/Uranium-238
MV-1	3/22/2011	10.8	8.89	1.21
	3/22/2011[a]	10.4	8.77	1.19
	5/25/2012	8.14	6.81	1.20
	5/22/2013	8.72	7.35	1.19
MV-2	3/22/2011	10.1	8.65	1.17
	5/24/2012	7.9	7.01	1.13
	5/22/2013	8.83	7.85	1.12
MV-3	3/22/2011	2.55	2.2	1.16
	5/25/2012	2.49	2.3	1.08
	5/21/2013	3.6	2.73	1.32
	5/21/2013[a]	3.58	2.84	1.26
HC-1	3/22/2011	0.9	0.609	1.48
	5/23/2012	0.401	0.35	1.15
	5/22/2013	0.425	0.291	1.46
HC-2	3/22/2011	45.2	45.3	0.998
	5/22/2012	38.1	36.2	1.05
	5/22/2013	37.2	37.2	1.00
HC-3	3/22/2011	NA	NA	NA
	5/23/2012	0.678	0.668	1.01
	5/22/2013	0.932	0.966	0.96
HC-4	3/23/2011	2.69	2.86	0.941
	5/24/2012[a]	14.4	15.1	0.95
	5/24/2012	14.2	14.8	0.96
	5/21/2013	22	20.8	1.06
HC-5	3/23/2011	0.264	0.117	2.26
	5/23/2012	0.227	0.126	1.80
	5/22/2013	0.240	0.122	1.97
HC-6	3/23/2011	15.4	13.5	1.14
	5/23/2012	14.4	12.2	1.18
	5/22/2013	15.7	12.6	1.25
HC-7	3/23/2011	5.9	4.78	1.23
	5/23/2012	16.1	13.9	1.16
	5/21/2013	6.31	5.56	1.13
HC-8	3/23/2011	NA	NA	NA
	5/25/2012	0.153	0.0553	2.77
	5/23/2013	0.107	0.041	2.61

[a] Indicates a duplicate sample.
NA = not applicable (samples not collected or samples not analyzed).

Table 3. Well Construction Details and September 2013 Head Data for Wells at the PSA

Well/Piezometer	TOC Elevation (ft amsl)	Water Depth (ft)[a]	Date	Elevation Water (ft amsl)[b]	Elevation TSZ (ft amsl)	Elevation BSZ (ft amsl)	Screen Length (ft)
MV-1	5,257.54	990.05	9/27/2013	4,267.49	3,684.81	3,531.00	153.81
MV-1 PZ	5,257.30	972.65	9/27/2013	4,284.65	3,919.80	3,859.80	60.00
MV-2	5,266.62	999.12	9/26/2013	4,267.50	3,446.75	3,275.98	170.77
MV-2 PZ	5,266.51	977.05[c]	9/26/2013	4,289.46[c]	4,078.82	4,019.32	59.50
MV-3	5,261.50	970.20	9/26/2013	4,291.30	3,797.91	3,626.75	171.16
MV-3 PZ	5,261.17	969.75	9/26/2013	4,291.42	4,120.75	4,060.72	60.03
HC-1	5,309.21	1,060.48	9/26/2013	4,269.94	4,236.01	3,997.12	238.89
HC-2	5,347.12	1,082.14	9/26/2013	4,265.42	4,392.12	4,124.12	268.00
HC-3	5,081.52	1,180.27	9/27/2013	3,921.25	3,918.52	3,898.02	20.50
HC-4	5,260.90	1,006.35	9/27/2013	4,258.35	4,247.90	3,957.90	281.00
HC-5	5,247.37	1,368.80	9/27/2013	3,878.57	1,862.37	1,716.77	145.60
HC-6	5,228.68	964.50	9/27/2013	4,265.07	4,112.70	3,996.38	116.32
HC-7	5,229.72	964.60	9/27/2013	4,265.35	4,123.25	4,006.12	117.13
HC-8	5,259.91	1,370.95	9/27/2013	3,889.52	2,965.51	2,848.99	116.52
H-2	4,017.06[d]	110.07	9/25/2013	3,906.99	3,377.06	3,237.06	140.00
H-3	4,232.30[d]	325.47	9/25/2013	3,906.83	3,919.30	3,762.30	157.00

[a] Depth-to-water measurements not corrected for borehole deviation. Depth-to-water measurements were collected prior to performing activities that disturb ambient water level conditions.
[b] Corrected for borehole deviation.
[c] Indicates the water level and/or groundwater elevation have not recovered from bailing.
[d] Indicates land surface elevation because TOC elevations are not available.
BSZ = (bottom of open interval; screened, perforated, or open hole).
NM = Not measured.
TOC = top of casing (well/piezometer).
TSZ = (top of open interval; screened, perforated, or open hole).
Elevation Water (true vertical depth [TVD] corrected), Water Depth (not TVD corrected).

Water levels in onsite wells west of the shear zone (detonation side) continued to rise from 0.67 ft in MV-1 to 1.84 ft in MV-3PZ (July 2012 to July 2013). The increase was less than the previous year for most wells but still too high to conclude that water levels are beginning to stabilize. Water levels in wells west of the shear zone at the site are 300 to 400 ft higher than those in wells east of the shear zone and in wells west of the site in Fourmile Flat. Refer to Appendix C (Figures C-1, C-2, and C-3) for hydraulic head data from 1996 to the present. Refer to Appendix D for a table showing annual water level changes in wells west of the shear zone from July 2007 through July 2013.

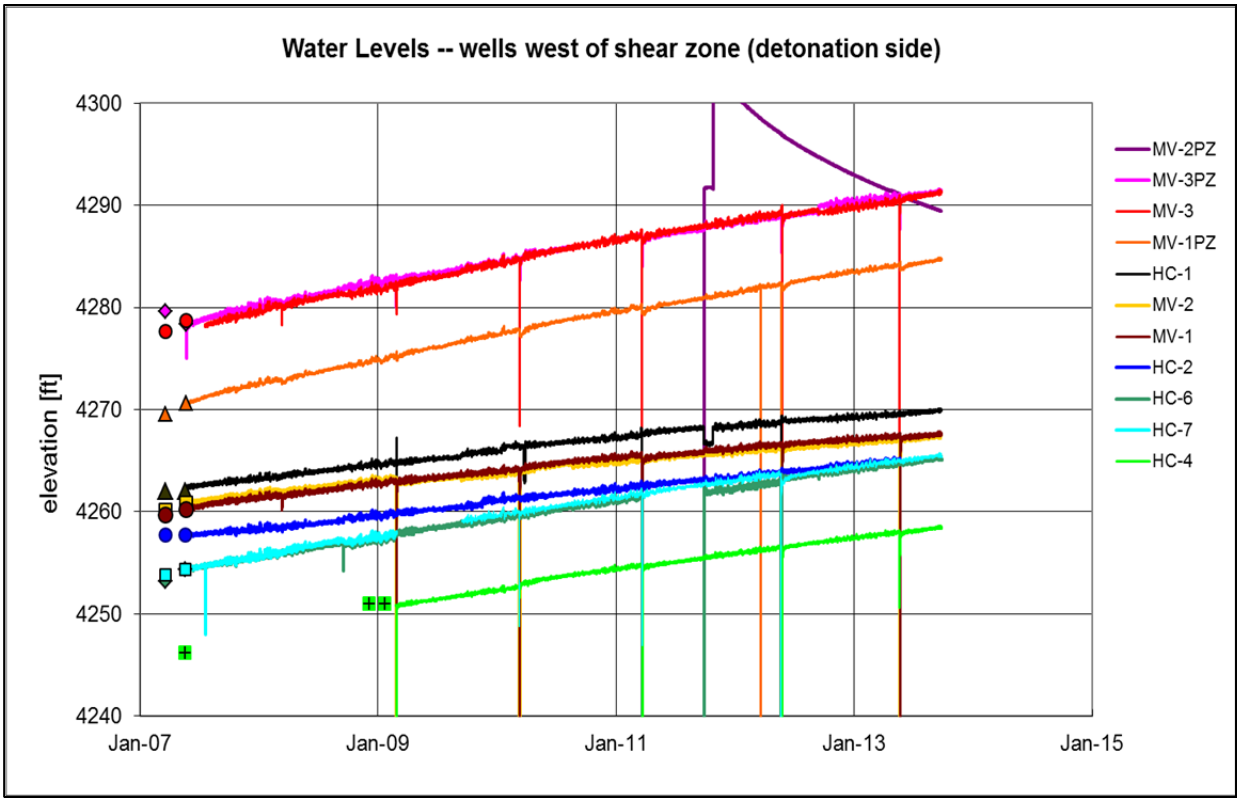

Figure 5. Hydrographs for Wells West of the Shear Zone

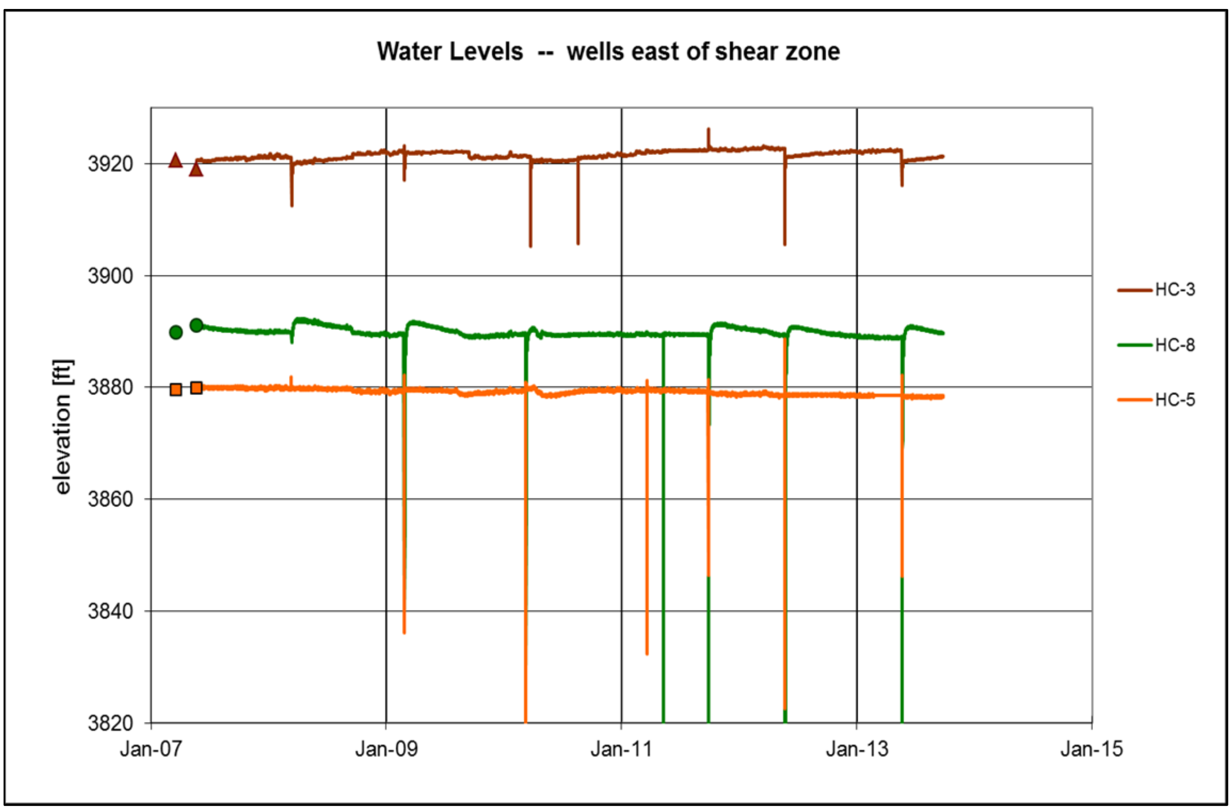

Figure 6. Hydrographs for Wells East of the Shear Zone

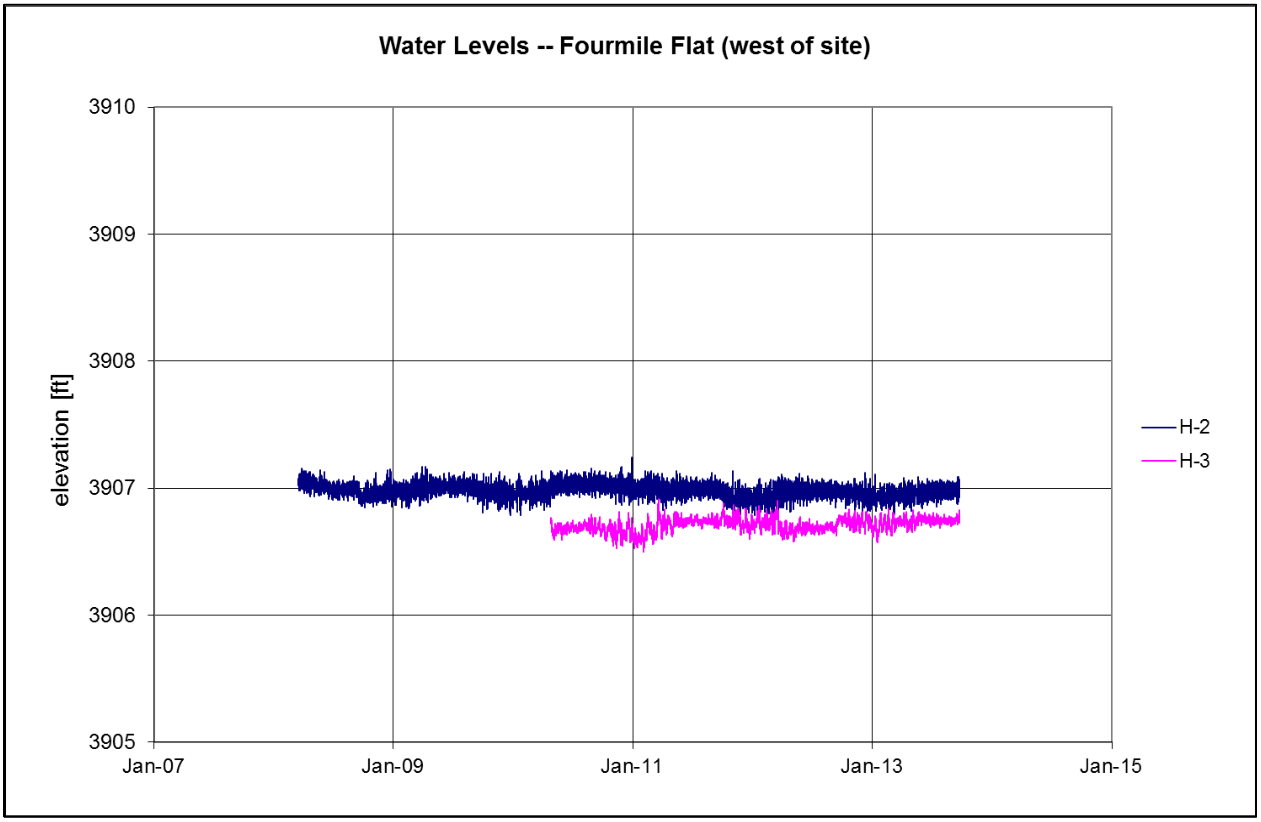

Figure 7. Hydrographs for Wells in Fourmile Flat

4.5 Rain Gage Monitoring Results

A Campbell Scientific tipping bucket rain gage with HOBO data logger was installed on August 8, 2012, to collect precipitation data at the site (Figure 2). The rain gage data logger was downloaded during the May 2013 sampling event but could not be downloaded during the September 2013 monitoring event. The rain gage was inspected, winterized, and a new battery was installed during the September monitoring event, but several attempts to connect to the data logger were unsuccessful. Communication with the data logger was reestablished by starting a new data collection test, but data through September 2013 could not be recovered. The data obtained for this monitoring period (October 2012 through May 2013) are presented with the historical data (August through September 2012) as Figure 8. The total precipitation measured from October 1, 2012 through May 21, 2013 was 2.7 inches. Precipitation data will continue to be included in future annual monitoring reports.

4.6 Seismograph Station Monitoring Results

A single temporary seismograph monitoring station was installed at the site on June 28, 2012. The seismograph station was installed as part of a feasibility test with the Nevada Seismological Laboratory (a research division of the College of Science at the University of Nevada-Reno) to assess potential micro-earthquake activity and determine if additional monitoring for local event locations would be beneficial for the site. Data obtained from the temporary seismograph station were presented in the *2012 Groundwater Monitoring Report, Project Shoal Area, Subsurface Corrective Action Unit 447* (DOE 2013b). Four micro-earthquake events were interpreted within an estimated 2 kilometers of the seismograph monitoring station, but because only one station was installed at the site, the locations and depths could not be determined. To locate the micro-earthquake events within the boundary of the PSA, it was recommended that four additional seismograph-monitoring stations be installed at the site. A cost estimate obtained for the continued monitoring with four additional monitoring stations determined that the cost for collecting these data was prohibitive. It was also uncertain whether data from the additional monitoring would be beneficial in advancing the SCM. Based on this information, LM and NDEP agreed during a meeting on May 8, 2013, that additional monitoring for micro-earthquake events was not warranted and the temporary seismograph station was removed.

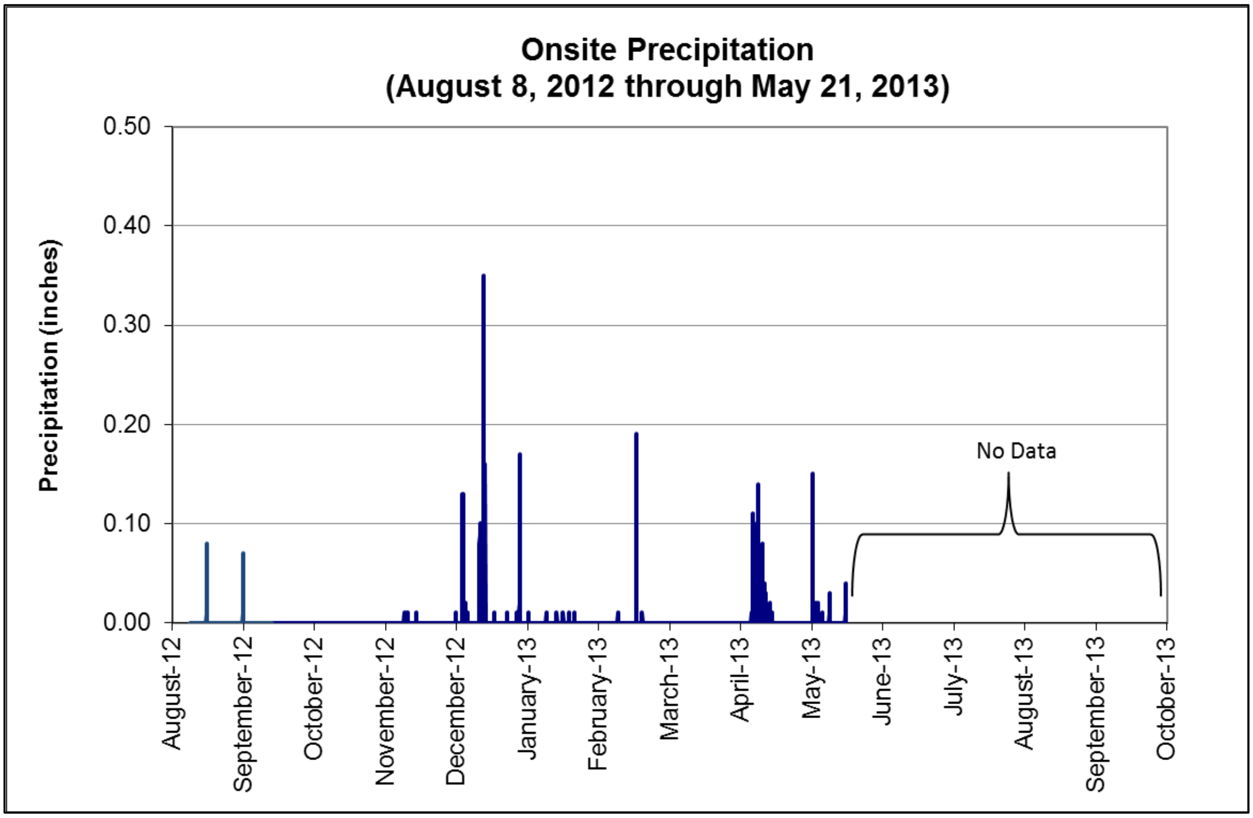

Figure 8. Precipitation Data, August 8 Through May 21, 2013

5.0 Site Inspection and Supplemental Site Activities

A site inspection was conducted as part of the September monitoring event that included measuring water levels, downloading transducers and rain gage, and inspecting the site roads, wellheads, and monument at surface ground zero for signs of damage. The rain gage, roads, wellheads, and monument were all in good condition at the time of the inspection in September. However, minor damage to the wellhead boxes that protect the MV-1 and MV-2 wellheads was observed at the time of the annual sampling in May. The damage appeared to be the result of gunshots and included a few holes in the wellhead boxes and minor damage to the pump electric cable for well MV-1. The wellhead boxes and pump electric cable were repaired during the annual sampling event in May. Supplemental activities performed during this annual monitoring period included the addition of well HS-1 to the sampling network. Results from the supplemental activities are provided in the following sections.

5.1 Enhanced Sampling Network

This sampling event was enhanced by including well HS-1 in the monitoring well sampling network. Well HS-1 is in Fairview Valley approximately 4-miles east of surface ground zero (Figure 2). The well is used by a local rancher to provide water for his livestock and has also been used to supply water for well drilling programs at the site. Samples were collected during this sampling event in preparation for future drilling projects to determine the geochemical properties of the water, estimate an apparent age of the water, and provide baseline radioisotope data. Samples were analyzed for major ions, stable isotopes of oxygen and hydrogen, carbon-14, tritium, uranium isotopes, gross alpha, and mass concentrations of uranium. Table A-2 in Appendix A presents a summary of the dissolved inorganic carbon-14 radioisotope calculation and age data from the annual sampling event. Table A-3 in Appendix A presents a summary of the water chemistry, stable isotope data, and radioisotope data obtained from the annual sampling event.

6.0 Summary

Analytical results from the 2013 monitoring event are generally consistent with those of the previous year. The sample collected from well HC-4 was the only sample with tritium detected above the laboratory's MDC. The tritium concentration was below the high of 1,130 pCi/L reported in 1998 (Pohll et al. 1998) and below the EPA-established tritium MCL of 20,000 pCi/L. Samples collected from wells HC-2, HC-4, and HC-6 had detectable gross alpha activity and uranium mass concentrations above the EPA-established MCLs of 15 pCi/L and 30 µg/L, respectively. The gross alpha activity and uranium mass concentrations observed in samples collected from wells HC-2 and HC-6 are consistent with historical trends. The concentrations of gross alpha and uranium mass detected in samples from well HC-4 increased from previous sampling events. These increases may be attributed to a greater pre-sampling purge volume during this sampling event than in previous years. If the gross alpha values in samples collected from wells HC-2, HC-4, and HC-6 are adjusted by subtracting activities of ^{234}U and ^{238}U, the values are less than zero, indicating that uranium accounts for all or nearly all gross alpha activity in these samples. Isotope ratios of uranium obtained during this monitoring event continue to support the interpretation of a natural source of uranium in groundwater rather than a nuclear-test-related source. Water level trends obtained from the 2013 water level data are consistent with those of previous years.

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Appendix A

Well Purge Data, Carbon-14 Calculation Data, Water Chemistry and Stable Isotope Data

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Table A-1. Monitoring Well Purge Data

Well	Date Sampled	Purged Volume (gallons)	Temperature (°C)	pH (s.u.)	Specific Conductance (μmhos/cm)
MV-1	5/22/2013	1000	22.70	8.28	677
			22.72	8.29	684
			22.74	8.28	684
MV-2	5/22/2013	1290	23.00	8.40	453
			23.01	8.39	459
			22.97	8.38	460
MV-3	5/21/2013	890	21.90	7.83	709
			21.95	7.84	710
			21.95	7.84	712
HC-1	5/22/2013	5	17.50	7.20	382
HC-2	5/22/2013	5	16.78	7.32	657
HC-3	5/22/2013	4	23.10	8.16	282
HC-4	5/21/2013	780	21.76	6.98	715
			21.77	7.05	712
			21.76	7.07	710
HC-5	5/21/2013	2760	27.20	8.60	915
			27.18	8.60	918
			27.26	8.60	916
HC-6	5/22/2013	5	19.16	6.23	1145
HC-7	5/21/2013	340	23.03	7.88	1257
			23.06	7.94	1256
			23.08	8.00	1262
HC-8	5/22/2013	3360	28.75	8.26	793
			28.73	8.27	795
			28.76	8.27	794

μmhos/cm = micromhos per centimeter
NA = not analyzed
s.u. = Standard Unit

Table A-2. Well HS-1 Dissolved Inorganic Carbon-14 Radioisotope Calculation and Age Data

Well ID	Sample Date	Mass Concentration Carbon (mg)	Fraction Modern Carbon	±1 s	Carbon-14 (pCi/L)[a]	Apparent Age (years)
HS-1	5/22/2013	4.10	0.0823	0.0017	0.00207	20,060

[a] Modern ^{14}C standard at 1950 AD has activity of 13.6 disintegrations per minute per gram C = 2.27 × 10^{-4} disintegrations per second (dps) per milligram (mg) C.
1 microcurie (µCi) = 3.7 × 10^{4} dps; therefore, modern ^{14}C standard at 1950 AD has activity of 6.135 × 10^{-9} µCi/mg.
mc = modern carbon; s = standard deviation

Example activity calculation (HS-1)

$$4.10\,\frac{mg\ C}{1\,L}\left(0.0823\,\frac{mg\ MC}{mg\ C}\right)\left(6.135\times10^{-9}\,\frac{\mu Ci}{mg\ MC}\right)\left(1\times10^{6}\,\frac{pCi}{\mu Ci}\right)=2.07\times10^{-3}\ \frac{pCi}{L}$$

Table A-3. Well HS-1 Water Chemistry, Stable Isotope, and Radioisotopic Data from 2013 Sampling Event

Monitoring Location	Sample Date	Temperature (°C)	pH (s.u.)	Specific Conductance (µmhos/cm)	Silica (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Bicarbonate (mg/L)	Stable Isotope Ratio		Tritium (pCi/L)	Uranium (µg/L)	Gross Alpha (pCi/L)	Uranium-234 (pCi/L)	Uranium-238 (pCi/L)
													Hydrogen ($^0/_{00}$)	Oxygen ($^0/_{00}$)					
HS-1	5/22/2013	19.05	7.98	421	67	35	5.5	42	7	33	55	120	-124.65	-15.78	<380	5.7	4.22	2.99	1.77

s.u. = Standard Unit
µmhos/cm = micromhos per centimeter
mg/L = milligrams per liter
$^0/_{00}$ = per mil (parts per thousand)

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Appendix B

Analytical Data: 2007 through Present

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Table B-1. Radioisotope and Chemical Sampling Results

Monitoring Location	Date	Carbon-14[a] (pCi/L)	Iodine-129 (pCi/L)	Tritium (pCi/L)	Uranium (µg/L)	Gross alpha (pCi/L)
MV-1	3/21/2007	<RDL (5.83E-03)[a]	<RDL (7.3E-11)	<359	42	25.6
	3/21/2007	NA	NA	NA	41[b]	21.5[b]
	3/11/2008	<RDL (2.49E-02)	<RDL (19.0E-11)	<180	21	14.0
	2/26/2009	<RDL (1.95E-02)	<RDL (10.5E-11)	<350	21	12.6
	3/11/2010	<RDL (1.93E-02)	<RDL (7.8E-11)	<300	21	11.3
	3/22/2011	NA	NA	<350	25	16.6
	3/22/2011[c]	NA	NA	<360	25	14.3
	5/25/2012	NA	NA	<300	22	14.3
	5/22/2013	NA	NA	<370	21	13.6
MV-2	3/21/2007	<RDL (1.77E-02)[a]	<RDL (8.3E-11)	<361	34	16.3
	3/21/2007	NA	NA	NA	34[b]	17.3[b]
	3/11/2008	<RDL (2.44E-02)	<RDL (29.5E-11)	<180	23	11.1
	2/26/2009	<RDL (2.13E-02)	NR	<360	24	12
	3/11/2010	<RDL (3.31E-02)	<RDL16.5 (E-11)	<300	21	13.8
	3/22/2011	NA	NA	<350	23	9.92
	5/24/2012	NA	NA	<300	22	10.6
	5/22/2013	NA	NA	<320	22	9.79
MV-3	3/21/2007	<RDL (5.90E-03)[a]	<RDL (13.5E-11)	<357	14	10.2
	3/21/2007	NA	NA	NA	14[b]	9.57[b]
	3/11/2008	<RDL (1.37E-02)	<RDL (18.0E-11)	<320	3.8	2.11
	2/26/2009	<RDL (8.37E-03)	<RDL (10.7E-11)	<360	3.8	<1.5
	3/12/2010	<RDL (1.29E-02)	<RDL (6.5E-11)	<300	4.2	2.63
	3/22/2011	NA	NA	<350	5.8	4.98
	5/25/2012	<RDL (1.06E-02)	NA	<300	7	2.72
	5/21/2013	NA	NA	<340	8	5.08
	5/21/2013[c]	NA	NA	<380	8	5.84
HC-1	3/21/2007	<RDL (1.52E-02)[a]	<RDL (9.6E-11)	<355	3.3	3.9
	3/21/2007	NA	NA	NA	3.4[b]	4.46[b]
	3/11/2008	<RDL (2.35E-02)	<RDL (4.9E-11)	<320	4.8	12.5
	2/26/2009	<RDL (2.01E-02)	NR	<360	1.4	<1.4
	3/24/2010	<RDL (3.18E-02)	<RDL (11.9E-11)	<310	3.3	4.93
	3/22/2011	NA	NA	<360	1.6	2.19
	5/23/2012	<RDL (1.23E-02)	NA	<300	1.1	<0.75
	5/22/2013	NA	NA	<340	0.9	3.19
HC-2	3/24/2010	<RDL(1.90E-02)	<RDL (2.5E-11)	<300	140	63.8
	3/22/2011	NA	NA	<360	120	197
	5/22/2012	NA	NA	<300	110	64.5
	5/22/2013	NA	NA	<330	100	61.1
HC-3	3/24/2010	<RDL (2.37E-02)	<RDL (541E-11)	<300	4.3	2.57
	3/22/2011	NA	NA	NA	NA	NA
	5/23/2012	<RDL (1.45E-02)	NA	<300	2	0.283
	5/22/2013	NA	NA	<350	2.7	0.724

Table B-1 (continued). Radioisotope and Chemical Sampling Results

Monitoring Location	Date	Carbon-14[a] (pCi/L)	Iodine-129 (pCi/L)	Tritium (pCi/L)	Uranium (µg/L)	Gross alpha (pCi/L)
HC-4	3/21/2007	<RDL (0.565)[a]	<RDL (32.4E-11)	<359	0.75	1.41
	3/21/2007	NA	NA	NA	0.85[b]	1.93[b]
	3/21/2007[c]	<RDL (0.436)[a]	<RDL (34.2E-11)	<359	0.69	1.75
	3/21/2007[c]	NA	NA	NA	0.81[b]	<0.876[b]
	3/11/2008	<RDL (2.06)	<RDL (21.5E-11)	555	4.5	2.88
	2/26/2009	<RDL (3.20)	<RDL (0.6E-11)	434	2.0	<1.4
	3/11/2010	<RDL (2.93)	<RDL (38.7E-11)	544	6.4	1.79[b]
	3/23/2011	NA	NA	554	8.9	3.82
	5/24/2012[c]	NA	NA	774	46	16.7
	5/24/2012	<RDL (2.50)	NA	803	46	22.9
	5/21/2013	NA	NA	964	60	35.1
HC-5	3/11/2010	<RDL (5.11E-03)	<RDL (1.1E-11)	<300	0.48	<1.5
	3/23/2011	NA	NA	<360	0.45	<2.1
	5/23/2012	<RDL (3.70E-03)	NA	<300	0.49	0.349
	5/22/2013	NA	NA	<340	0.40	0.957
HC-6	3/24/2010	<RDL (1.14E-02)	<RDL (5.6E-11)	<300	35	25.7
	3/23/2011	NA	NA	<360	37	20.4
	5/23/2012	<RDL (1.16E-02)	NA	<300	38	14.1
	5/22/2013	NA	NA	<360	36	19.1
HC-7	3/11/2010	<RDL (5.31E-03)	<RDL (3.0E-11)	<300	7.4	5.77
	3/23/2011	NA	NA	<360	13	10.6
	5/23/2012	NA	NA	<300	41	23.9
	5/21/2013	NA	NA	<370	15	13.8
HC-8	3/10/2010	<RDL (9.63E-03)	<RDL (1.3E-11)	<300	0.25	<1.3
	3/23/2011	NA	NA	NA	NA	NA
	5/25/2012		NA	<300	0.2	0.454
	5/23/2013	NA	NA	<380	0.14	1.24

[a] Estimated based on sample volume of 200 milliliters for 2007 samples.
[b] Indicates the sample was filtered.
[c] Indicates a duplicate sample.
NA = not applicable (samples not collected or samples not analyzed).
NR = not run, because sample bottle was broken during shipment to the laboratory.
<RDL = below required detection limit with laboratory result in parentheses; RDL is 5 pCi/L for ^{14}C, 0.1 pCi/L for ^{129}I, 400 pCi/L for tritium, 50 µg/L for uranium, and 4 pCi/L for gross alpha (DOE/NNSA 2006).

Table B-2. Uranium Isotope Sampling Results

Monitoring Location	Date	Uranium-234 (pCi/L)	Uranium-238 (pCi/L)	Uranium-234/Uranium-238
MV-1	3/21/2007	16.8[a]	14.2[a]	1.18[a]
	3/21/2007	15.4	12.6	1.22
	3/11/2008	7.35	6.2	1.19
	2/26/2009	8.75	6.98	1.25
	3/11/2010	9.06	7.64	1.19
	3/22/2011	10.8	8.89	1.21
	3/22/2011[b]	10.4	8.77	1.19
	5/25/2012	8.14	6.81	1.20
	5/22/2013	8.72	7.35	1.19
MV-2	3/21/2007	13.6[a]	11.4[a]	1.19[a]
	3/21/2007	13.2	11.7	1.13
	3/11/2008	8.95	7.89	1.13
	2/26/2009	8.64	6.7	1.29
	3/11/2010	9.66	8.32	1.16
	3/22/2011	10.1	8.65	1.17
	5/24/2012	7.9	7.01	1.13
	5/22/2013	8.83	7.85	1.12
MV-3	3/21/2007	4.64[a]	4.37[a]	1.06[a]
	3/21/2007	5.47	4.68	1.17
	3/11/2008	1.47	1.17	1.25
	2/26/2009	1.33	0.998	1.33
	3/12/2010	1.7	1.42	1.20
	3/22/2011	2.55	2.2	1.16
	5/25/2012	2.49	2.3	1.08
	5/21/2013	3.6	2.73	1.32
	5/21/2013[b]	3.58	2.84	1.26
HC-1	3/21/2007	1.28[a]	1.19[a]	1.08[a]
	3/21/2007	1.4	1.19	1.18
	3/11/2008	1.84	1.51	1.21
	2/26/2009	0.572	0.385	1.49
	3/24/2010	1.24	1.05	1.18
	3/22/2011	0.9	0.609	1.48
	5/23/2012	0.401	0.35	1.15
	5/22/2013	0.425	0.291	1.46
HC-2	3/24/2010	45.1	45.3	0.996
	3/22/2011	45.2	45.3	0.998
	5/22/2012	38.1	36.2	1.05
	5/22/2013	37.2	37.2	1.00
HC-3	3/24/2010	1.16	1.21	0.96
	3/22/2011	NA	NA	NA
	5/23/2012	0.678	0.668	1.01
	5/22/2013	0.932	0.966	0.96

Table B-2 (continued). Uranium Isotope Sampling Results

Monitoring Location	Date	Uranium-234 (pCi/L)	Uranium-238 (pCi/L)	Uranium-234/Uranium-238
HC-4	3/21/2007	0.349[a]	0.308[a]	1.12[a]
	3/21/2007[b]	0.313[a]	0.33[a]	0.95[a]
	3/21/2007	0.293	0.305	0.96
	3/21/2007[b]	0.31	0.336	0.92
	3/11/2008	1.53	1.63	0.94
	2/26/2009	0.654	0.722	0.91
	3/11/2010	2.27[a]	1.95[a]	1.16[a]
	3/23/2011	2.69	2.86	0.941
	5/24/2012[b]	14.4	15.1	0.95
	5/24/2012	14.2	14.8	0.96
	5/21/2013	22	20.8	1.06
HC-5	3/11/2010	0.295	0.173	1.71
	3/23/2011	0.264	0.117	2.26
	5/23/2012	0.227	0.126	1.80
	5/22/2013	0.240	0.122	1.97
HC-6	3/24/2010	14.4	12.2	1.18
	3/23/2011	15.4	13.5	1.14
	5/23/2012	14.4	12.2	1.18
	5/22/2013	15.7	12.6	1.25
HC-7	3/11/2010	3.43	3.08	1.11
	3/23/2011	5.9	4.78	1.23
	5/23/2012	16.1	13.9	1.16
	5/21/2013	6.31	5.56	1.13
HC-8	3/10/2010	0.187	0.101	1.85
	3/23/2011	NA	NA	NA
	5/25/2012	0.153	0.0553	2.77
	5/23/2013	0.107	0.041	2.61

[a] Indicates the sample was filtered.
[b] Indicates a duplicate sample.
NA = not applicable (samples not collected or samples not analyzed)

Appendix C

Hydraulic Head Data: 1996 through Present

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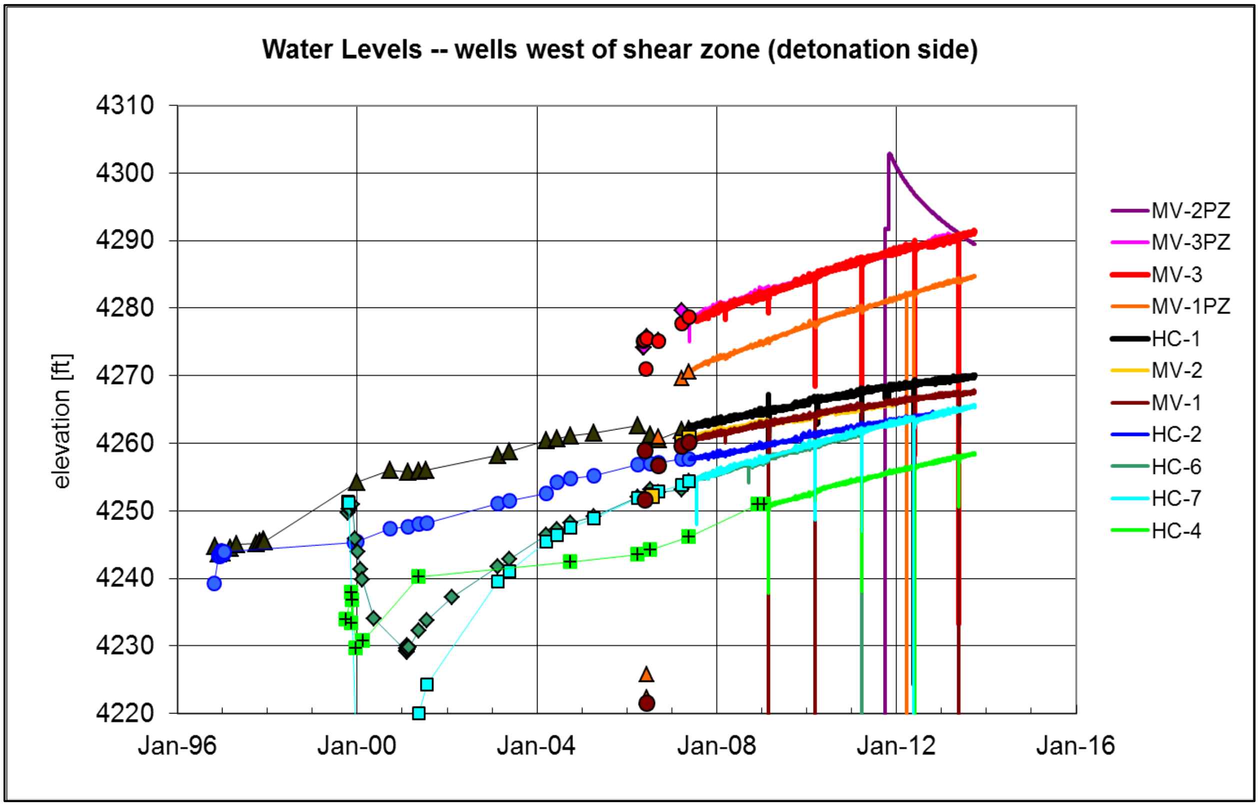

Figure C-1. Hydrographs for Wells West of the Shear Zone (expanded scale on Y axis)

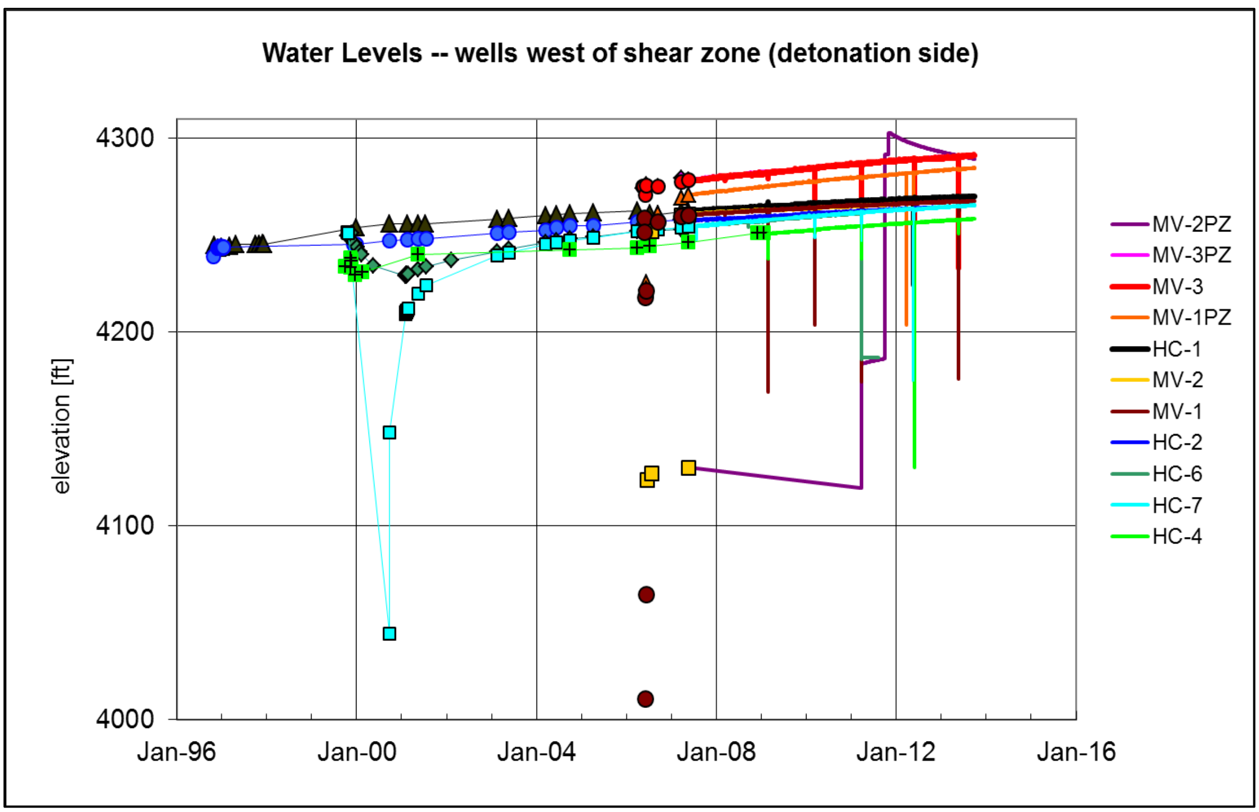

Figure C-2. Hydrographs for Wells West of the Shear Zone

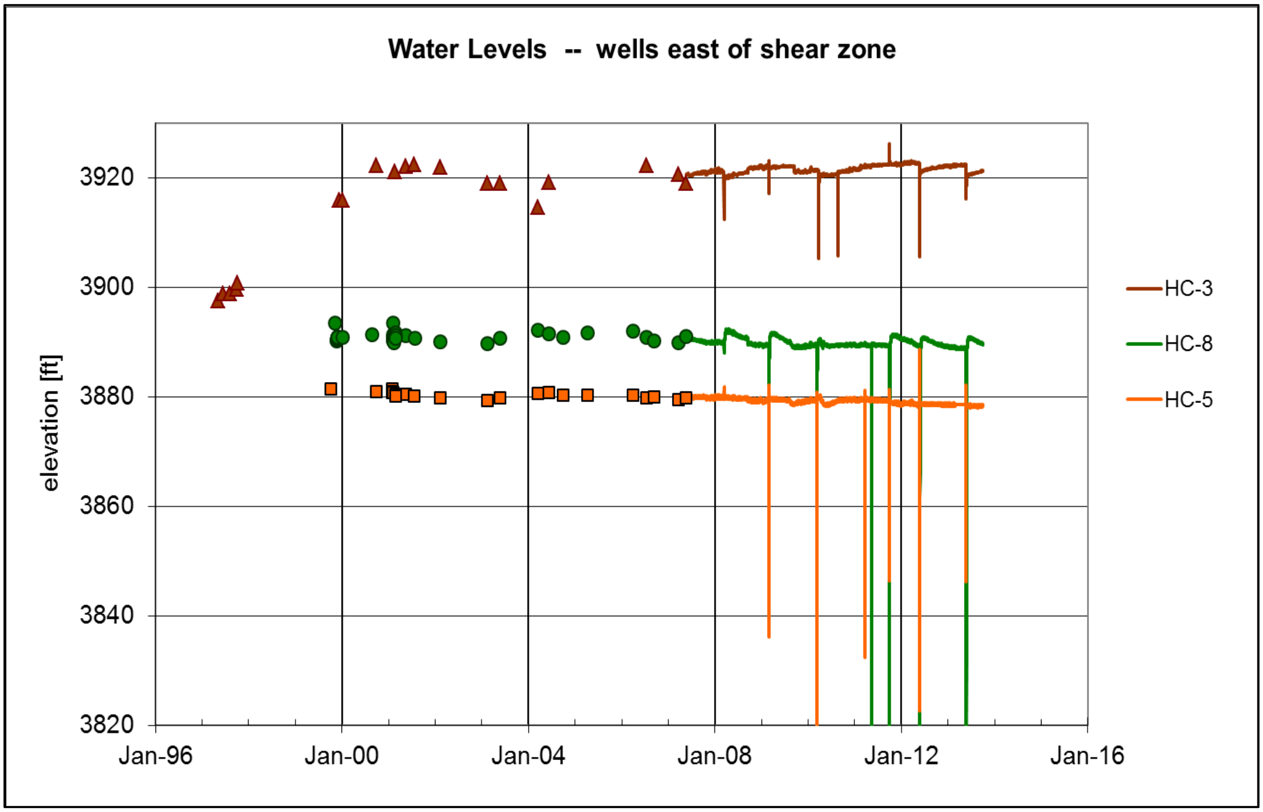

Figure C-3. Hydrographs for Wells East of the Shear Zone

Appendix D

Annual Water Level Changes in Wells West of Shear Zone: July 2007 through July 2013

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Table D-1 Annual Water Level Changes in Wells West of the Shear Zone

Date Range	Wells/Piezometers West of Shear Zone (water level change in feet/year)										
	MV-1	**MV-1PZ**	**MV-2**	**MV-2PZ**	**MV-3**	**MV-3PZ**	**HC-1**	**HC-2**	**HC-4**	**HC-6**	**HC-7**
7/1/2007–7/1/2008	1.52	2.67	1.37	NM	2.71	2.57	1.40	1.09	NM	2.00	2.28
7/1/2008–7/1/2009	1.40	2.48	0.95	NM	2.16	2.20	1.32	1.40	NM	1.96	NM
7/1/2009–7/1/2010	1.38	2.48	1.36	NM	2.54	2.23	1.49	1.49	2.12	1.79	NM
7/1/2010–7/1/2011	0.79	1.80	0.76	NM	1.82	1.67	1.21	1.02	1.46	NM	1.64
7/1/2011–7/1/2012	1.23	2.10	0.94	NM	1.78	1.91	1.08	1.24	1.72	NM	NM
7/1/2012–7/1/2013	0.67	1.71	0.85	NM	1.65	1.84	0.72	1.34	1.35	1.44	1.59

NM = Not Measured, because transducer data were not available.

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Appendix E

NDEP Correspondence with Record of Review and Response to Comments

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STATE OF NEVADA
Department of Conservation & Natural Resources
DIVISION OF ENVIRONMENTAL PROTECTION

NEVADA DIVISION OF ENVIRONMENTAL PROTECTION
protecting the future for generations

Brian Sandoval, Governor
Leo M. Drozdoff, P.E., Director
Colleen Cripps, Ph.D., Administrator

January 27, 2014

Mr. Mark Kautsky
Site Manager
U. S. Department of Energy
Office of Legacy Management
2597 Legacy Way
Grand Junction, CO 81503

RE: Draft 2013 Groundwater Monitoring Report, Project Shoal Area, Subsurface Corrective Action Unit 447, Shoal, Nevada, Site
December 2013
Federal Facility Agreement and Consent Order

Dear Mr. Kautsky:

The Nevada Division of Environmental Protection, Bureau of Federal Facilities (NDEP) has received and reviewed the U. S. Department of Energy, Office of Legacy Management's *Draft 2013 Groundwater Monitoring Report, Project Shoal Area, Subsurface Correction Action Unit 447, Shoal, Nevada, Site* (Report) received on January 9, 2014. While this letter serves as a Notice of Completion for the milestone deadline of January 15, 2014 for the Draft 2013 Monitoring Report, pursuant to Subpart XXV.1 of the FFACO, the NDEP does have the following comments or questions on the Report which should be addressed in the Final version of the Report:

1. Page v, Executive Summary, Second Paragraph, Last Sentence: It is requested that the phrase "to the mutual agreement of DOE-OLM and NDEP" be added to the end of this sentence.

2. Page 3, Section 2.1, Last Paragraph: As the 2011 data acquisition plan and described work are in the past, this paragraph should be written in the past tense.

3. Page 8, Section 4.1, Third Full Sentence on Page: The year the record of technical change was submitted and approved should be included in this sentence.

4. Page 14, Figure 5: The symbol for Well MV-2PZ data does not appear the same on the legend and the Figure. Page C-1 has two additional charts that express this data better. While not an error on Figure 5, it is confusing and could be made clearer as the Figures on Page C-1 illustrate.

5. Page 7, Section 4.0, First paragraph, Third Last Sentence and Page 15, Section 4.5: The location of the rain gauge mentioned in these two paragraphs should be noted on one of the Figures in the report.

6. Page 17, Section 6.0: Though the title of this Section is **Summary and Recommendations** there are no Recommendations presented. This discrepancy should be corrected either by adding Recommendations to the paragraph or correcting the Section title.

Please address any questions regarding this matter to Chris Andres at (702) 486-2850, ext. 232.

Sincerely,

Tim Murphy

T. H. Murphy
Chief
Bureau of Federal Facilities

THM/CDA

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FFACO Group, SNJV, Las Vegas, NV
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R. Hutton, Stoller, Grand Junction, CO
R. Findlay, Stoller, Grand Junction, CO

Record of Review

Due Date	Review No.	Project	Type of Review
	1	Project Shoal	Draft Report - Technical Review

Document Title and\or Number and Revision
2013 Groundwater Monitoring Report Project Shoal Area Subsurface Corrective Action Unit 447 (S11217)

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Reviewers' Recommendation

- ☐ Release Without Comment
- ☐ Consider Comments
- ☐ Resolve Comments and Reroute for Review

Signature of Reviewer and Date

- ☒ Comments Have Been Addressed

Mark Kautsky
Digitally signed by Mark Kautsky
Date: 2014.02.14 09:35:00 -08'00'

Signature of Author and Date

- ☒ Comment Resolution Satisfactory
- ☐ Comment Resolution Unsatisfactory

Christine Andres 2/14/14

Signature of Reviewer and Date

Item No.	Reviewer's Comments and Recommendation	Reqd. (Y/N)	Item No.	Author's Response (if required)
1	Page v, Executive Summary, Second Paragraph, Last Sentence: It is requested that the phrase "to the mutual agreement of DOE-OLM and NDEP" be added to the end of this sentence.	Y	1	The sentence was revised to include the requested phrase.
2	Page 3, Section 2.1, Last Paragraph: As the 2011 data acquisition plan and described work are in the past, this paragraph should be written in the past tense.	Y	2	The paragraph was revised to be in past tense as requested.
3	Page 8, Section 4.1, Third Full Sentence on Page: The year the record of technical change was submitted and approved should be included in this sentence.	Y	3	The sentence was revised as follows: "A record of technical change was submitted to NDEP and approved by NDEP in March 2012 to change the RDL to 400 pCi/L in the CADD/CAP."
4	Page 14, Figure 5: The symbol for Well MV-2PZ data does not appear the same on the legend and the Figure. Page C-l has two additional charts that express this data better. While not an error on Figure 5, it is confusing and could be made clearer as the figures on Page C-1 illustrate.	Y	4	Figure 5 was revised to be consistent with the charts in Appendix C. Figure numbers (Figures C-1, C-2, and C-3) were also added to the charts in Appendix C and referenced in the text to reduce confusion.

Record of Review (continuation)

Review No. 1	Project Shoal

Item No.	Reviewer's Comments and Recommendation	Reqd. (Y/N)	Item No.	Author's Response (if required)
5	Page 7, Section 4.0, First paragraph, Third Last Sentence and Page 15, Section 4.5: The location of the rain gauge mentioned in these two paragraphs should be noted on one of the Figures in the report.□	Y	5	The location of the rain gage was added to Figure 2 and the Figure 2 reference was added to both sections as requested.
6	Page 17, Section 6.0: Though the title of this Section is Summary and Recommendations there are no Recommendations presented. This discrepancy should be corrected either by adding Recommendations to the paragraph or correcting the Section title.	Y	6	The Section 6.0 title was revised to remove recommendations because no recommendations are provided for this monitoring period.

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